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Carbohydrates

Biochemistry

Definition, classification, structure and functions of carbohydrates, monosaccharides, disaccharides, polysaccharides, digestion, absorption and clinical importance.

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CHAPTER 02

Carbohydrates

Classification, structures, functions, digestion and absorption

1. Definition and chemical structure

Carbohydrates are polyhydroxy aldehydes or ketones, or substances that yield them on hydrolysis. Many have a general empirical formula resembling (CH2O)n, although exceptions occur. They contain carbon, hydrogen and oxygen. Glucose is an aldohexose, fructose a ketohexose and ribose a pentose. Sugars may form cyclic rings in solution. Anomeric carbon configuration gives alpha and beta forms, which influence glycosidic linkages.

2. Classification

Class	Examples	Key feature
Monosaccharides	Glucose, fructose, galactose, ribose	Cannot be hydrolysed into simpler sugars
Disaccharides	Sucrose, lactose, maltose	Two monosaccharides linked by a glycosidic bond
Oligosaccharides	Raffinose, cell-surface oligosaccharides	Short chains of sugar units
Polysaccharides	Starch, glycogen, cellulose	Long chains of sugar units

Disaccharide	Components	Bond / property
Maltose	Glucose + glucose	alpha(1 -> 4); reducing
Lactose	Galactose + glucose	beta(1 -> 4); reducing
Sucrose	Glucose + fructose	alpha(1 -> 2)beta; non-reducing

Reducing sugars have an available anomeric group that can reduce certain reagents. Benedict's test detects reducing substances but is not specific for glucose and is not the preferred modern diagnostic blood glucose test.

3. Polysaccharides

- Starch: plant energy store; amylose is largely linear alpha(1 -> 4) glucose, amylopectin has alpha(1 -> 6) branches.
- Glycogen: highly branched glucose polymer stored mainly in liver and skeletal muscle.
- Cellulose: beta(1 -> 4) glucose polymer; human enzymes cannot digest it. It contributes to dietary fibre.

- Glycosaminoglycans: complex carbohydrates in connective tissues, e.g., hyaluronic acid and heparin.

4. Functions

Glucose supplies energy (approximately 4 kcal/g of digestible carbohydrate). Glycogen provides a readily mobilized reserve; ribose and deoxyribose form nucleotides. Glycoproteins and glycolipids participate in cell recognition. Dietary fibre supports bowel function and may help improve glycaemic and lipid profiles.

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5. Digestion and absorption

Site	Enzyme / process	Products
Mouth	Salivary amylase	Shorter starch chains and maltose
Stomach	Acid progressively inactivates salivary amylase	Little further carbohydrate digestion
Small intestine	Pancreatic amylase	Maltose, maltotriose and limit dextrins
Brush border	Maltase, sucrase-isomaltase, lactase	Glucose, galactose, fructose

Glucose and galactose enter enterocytes through sodium-dependent SGLT1; fructose enters by facilitated diffusion through GLUT5. Monosaccharides leave mainly via GLUT2 and enter the hepatic portal blood. Indigestible fibre reaches the colon, where some is fermented to short-chain fatty acids.

6. Monosaccharides: detailed classification

Monosaccharides can be classified according to the number of carbon atoms and the position of the carbonyl group. Aldoses contain an aldehyde group in their open-chain form; ketoses contain a ketone group.

Carbon number	Aldose example	Ketose example
3 (triose)	Glyceraldehyde	Dihydroxyacetone
5 (pentose)	Ribose	Ribulose
6 (hexose)	Glucose, galactose, mannose	Fructose

Important monosaccharides

- Glucose is absorbed from food and can also be formed by the liver. It is the usual major fuel for the brain and the essential energy source for mature red blood cells.
- Fructose is present in fruits and honey and is a component of sucrose.
- Galactose is released during lactose digestion and contributes to glycoprotein and glycolipid synthesis.
- Ribose forms part of RNA, ATP and nucleotide coenzymes; deoxyribose is present in DNA.

7. Comparison of starch, glycogen and cellulose

Feature	Starch	Glycogen	Cellulose

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Occurrence	Plants	Animals	Plant cell walls
Glucose linkage	alpha(1 -> 4), some alpha(1 -> 6)	alpha(1 -> 4), frequent alpha(1 -> 6)	beta(1 -> 4)
Function	Energy storage	Short-term glucose reserve	Structural support
Human digestion	Yes	Yes	No by human enzymes

8. Carbohydrate derivatives and laboratory identification

Amino sugars contribute to extracellular matrix and cell-surface molecules; sugar acids such as glucuronic acid participate in conjugation reactions. Glycosylation is enzyme-directed attachment of sugars to proteins or lipids; glycation is nonenzymatic attachment, as in HbA1c formation.

The iodine test gives a blue-black colour with amylose-rich starch. Benedict's reagent can indicate reducing substances; it is a historical qualitative test and cannot establish a modern

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diagnosis of diabetes.

9. Clinical importance and nursing applications

Lactase deficiency causes lactose malabsorption, bloating and diarrhoea. In diabetes, glucose homeostasis is impaired. In galactosaemia, inherited enzyme defects cause accumulation of galactose metabolites. Recognize diarrhoea, dehydration and symptoms of glucose abnormality; follow prescribed diet and monitor glucose when indicated. Dietary advice must be individualized; carbohydrate restriction is not appropriate for every patient.

10. Important Examination Questions

Long Answer Questions

1. 1. Classify carbohydrates and describe digestion and absorption.
2. 2. Describe monosaccharide classification and the properties of disaccharides.
3. 3. Compare starch, glycogen and cellulose and discuss their functions.

Short Answer Questions

1. 1. Write a short note on Reducing sugars.
2. 2. Write a short note on glycogen versus starch.
3. 3. Write a short note on lactose intolerance.

Very Short Answer Questions

1. 1. Name the storage carbohydrate of animals. - Glycogen.
2. 2. Which enzyme digests lactose? - Lactase.
3. 3. What transporter absorbs fructose at the intestinal apical membrane? - GLUT5.
4. 4. Give two examples of reducing disaccharides. - Maltose and lactose.

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Additional objective question

Which sugar is non-reducing? - Sucrose.

11. Quick Revision

- Monosaccharides contain one sugar unit; disaccharides contain two.
- Sucrose is glucose plus fructose; lactose is galactose plus glucose.
- Glycogen is more highly branched than amylopectin.
- Brush-border enzymes release absorbable monosaccharides.

Conclusion

Carbohydrates provide energy and important structural molecules; their digestion and absorption explain common clinical problems such as lactose intolerance and altered glucose metabolism.

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Practice questions

Choose one best answer. The answer key and explanations follow the questions.

1. Which monosaccharides form lactose?

A. Glucose and fructose
B. Galactose and glucose
C. Glucose and glucose
D. Fructose and galactose

2. Which transporter absorbs fructose across the intestinal apical membrane?

A. SGLT1
B. GLUT4
C. GLUT5
D. GLUT2

3. Which glucose polymer cannot be digested by human enzymes?

A. Glycogen
B. Amylose
C. Amylopectin
D. Cellulose

4. A patient with diabetes is sweating and trembling, is alert and can swallow. Capillary glucose is 54 mg/dL. Which problem needs prompt attention?

A. Hypoglycaemia requiring the local hypoglycaemia protocol
B. A normal fasting glucose value
C. Hyperglycaemic crisis confirmed by this reading
D. A result that should be ignored until the next day

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Answer key and explanations

1. B - Galactose and glucose

Lactose consists of galactose plus glucose.

2. C - GLUT5

Fructose enters enterocytes by GLUT5-mediated facilitated diffusion.

3. D - Cellulose

Human enzymes cannot digest cellulose's beta(1 -> 4) linkages.

4. A - Hypoglycaemia requiring the local hypoglycaemia protocol

A glucose value below 70 mg/dL with compatible symptoms requires prompt assessment and treatment according to protocol. Swallowing and consciousness determine safe treatment options.

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